BIOVENTING – PLEASE KEEP IT SIMPLE!

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Introduction

In the 1980s the Air Force determined that they had over 2,500 sites contaminated with fuel hydrocarbons. In 1985, the Air Force begin to investigate low-cost methods for cleanup of fuel contaminated soils and discovered, during an SVE demonstration in 1988, that significant biodegradation was occurring as a result of air infusion to the subsurface. This observation was subsequently studied in detail (1989/1990) and optimized to provide a viable low-cost alternative for treating fuel contaminated soil. In 1991, AFCEE launched a large-scale nationwide demonstration of the technology to determine extent of application and to sell the regulatory community on its use. As a result of this research and nationwide initiative, bioventing today stands alongside SVE as a proven technology.

Bioventing is the process of aerating soils to stimulate in situ biological activity and promote bioremediation. Bioventing typically is applied in situ to the vadose-zone and is applicable to any chemical that can be aerobically biodegraded, but to date has been implemented primarily at petroleum-contaminated sites. A typical bioventing system injects air at a low rate into the vadose-zone. Although bioventing is related to the process of soil vacuum extraction (SVE), the primary objectives of these two bioremediation technologies are different. Soil vacuum extraction is designed and operated to maximize the volatilization of low-molecular-weight compounds, with some biodegradation occurring. In contrast, bioventing is designed to maximize biodegradation of aerobically biodegradable compounds, regardless of their molecular weight, with minimal or no volatilization to the atmosphere occurring (note: this paragraph was taken directly from the AFCEE bioventing web-site).

The Air Force bioventing program has resulted in numerous protocols and design guides including:

- Test Plan and Technical Protocol for a Field Treatability Test for Bioventing (1992)
- Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing Using Soil Gas Survey to Determining Bioventing Feasibility and Natural Attenuation Potential
- Bioventing Design Tool
- Principles and Practices of Bioventing (1995)
- A General Evaluation of Bioventing for Removal Actions at Air Force/Department of Defense Installations Nationwide (June 1996)
- Bioventing Performance and Cost Results From Multiple Air Force Test Sites (June 1996)

Methods

Since its beginnings in 1989, bioventing has been research, analyzed, and implemented at thousands of sites. Many of the original evaluation methods were developed in an atmosphere of defensible research that was critical in understanding the technology and providing indisputable evidence to the regulatory community regarding the efficacy of the new and innovative approach. With the technology moving from development and demonstration to wide-spread use, some of the methods and techniques originally developed are no longer necessary for successful implementation and monitoring.

Bioventing was developed to provide a low cost solution for fuel contaminated soil in the vadose zone. However, with any technology, it is easy to make bioventing expensive and less competitive. The key to continued successful use of bioventing is a clear understanding of the current protocols and design guides combined with the understanding that bioventing has graduated from an innovative to a proven technology. Many of the techniques and methods in the early protocols have carried over into proven operating systems and are generating both unnecessary capital and O&M costs. This paper attempts to clarify which of those early bioventing pilot study principles and techniques are still necessary and which pilot study methods are not necessary for monitoring operating systems

Discussion

Bioventing Pilot Study – Underlying Principle

1. The technology was not proven and pilot tests had to provide indisputable evidence
    a. Air and helium injected during respiration test
        i. Ensure you were extracting the same air
        ii. Ensure you were not diluting or short circuiting
        iii. Not necessary at most locations if sampling is conducted carefully
2. The original concept was to design system primarily on oxygen ROI
    a. Respiration rates were found to decline rapidly
    b. A better design is somewhere between air ROI and oxygen ROI

Bioventing Pilot Study – Purpose

1. Evaluate site potential
2. Provide information for system design

Evaluate site potential

1. Screen site for biodegradation potential by collecting and evaluating oxygen and carbon dioxide concentrations in soil gas.
    a. If you have high TVH and high oxygen the site has little potential
    b. Experience indicates this will almost never occur
        i. If this happens at your site suspect poor sampling technique
    c. Determine if bioventing will likely increase degradation rate
    d. If site has greater than 5% oxygen, bioventing probably won’t help

Provide information for system design

1. Determine the air injection or extraction radius of influence (ROI) for system design
    e. Use SVE methods
    f. Rule of thumb - > 1” vacuum/pressure
2. Determine the oxygen radius of influence for system design
    a. This requires a respiration test to measure oxygen utilization rate
3. Using air injection ROI, and oxygen ROI, design system spacing and injection rate
    a. Consider rate at which respiration rates is likely to decline

Uses of the Respiration Test

1. Determines oxygen ROI for assisting in design
    a. Not the sole basis; use experience
2. Provides integrated estimate of remedial progress
3. Provides best indication of when site is clean
4. Estimates fuel biodegradation rate/mass removal

Lessons learned that impact the pilot test

1. Direct reading equipment is designed to operate at atmospheric pressure
    a. Direct reading sampling equipment cannot be used to pull the vacuum
        i. High potential for leakage and dilution with atmospheric air
        ii. Misinterpreted as low or no respiration or generally high site oxygen
            1. Could discourage use of the technology
    b. Always use vacuum sampling pump for soil gas measurements

2. Some lower quality vacuum pumps leak under vacuum
    a. Mitigated by using Tedlar or Mylar bag and a vacuum desiccator
    c. Direct reading equipment samples from the bag
    d. Check sampling pump leakage by comparing vacuum desiccator measurements to those from the discharge of the sampling pump
    e. If no leakage then its faster to sample from the discharge side of the sampling pump
        i. Take a side stream to maintain atmospheric pressure
3. Watch oxygen concentrations to capture low point
    a. Cleary shows when purging is complete
    b. Too much purging can bring in atmospheric air in shallow probes
4. Careful sampling and cross checking eliminates need for helium injection
5. Direct reading instrument (LEL/explosive meter) best for collecting hydrocarbon concentrations
    a. Catalytic detector linear over a wider range than FID

Operating Bioventing Systems

1. An operating system is a sold system
    a. No longer need pilot level detail
    b. Periodic (annual) respiration tests to monitor progress
2. Respiration test provides integrated estimate of remedial progress
    a. Avoid periodic soil sampling to measure progress
        i. Variability is recipe for confusion
        ii. Minimizing OM&M encourages longer operation
        iii. "JUST SET IT AND FORGET IT" - almost
3. Never inject air or helium into VMP on an operating system for respiration test
    a. If the VMP doesn't show >5% oxygen during operation adjust injection spacing and/or flow rate
    b. Get initial oxygen and carbon dioxide while system is running
    c. Turn off blower/s and start respiration test
        i. Its not a pilot test anymore
4. Delay soil samples until respiration rate is at background rates
    a. Minimizes unnecessary, costly, and confusing soil data
    b. Minimize periodic vapor sampling
5. Estimate fuel biodegradation rate/mass removal
    a. Don't get caught up in quantifying mass removal rate
    b. Intended as an estimate only
    c. Not really important since starting mass is never known
    d. Focus is on oxygen utilization rate for determining endpoint
6. Minimize OM&M costs
    a. Avoid the trap of collecting periodic soil samples
    b. Know how you will use any periodic VOC data or don't collect it
    c. Minimize respiration tests (annual is adequate)
7. Keep it running and keep it simple
    a. Consider hard-wiring so system does not need to be restarted after power outage (only for injection mode)
    b. Use telemetry technology to check on operating status
    c. Understand the pitfalls of periodic sampling and fight against it

References

As listed in the introduction above.